The background of the slide is a scenic photograph of a mountain lake. In the foreground, there is a calm body of water reflecting the sky. The middle ground shows steep, forested mountainsides. In the background, more mountain peaks are visible under a clear blue sky. The overall tone is natural and serene.

Do Hydraulic Conductivity Values in Varying Geologic Settings Depend on Selection of Slug Testing Field Methods and Data Evaluation Techniques?

Developed and presented by:

**Amy Martinez, R.S. Project
Hydrogeologist**



- 💧 **Local Environmental Consultants**
- 💧 **Specializing in Water and Wastewater**
- 💧 **Staff Comprised of Former Regulators w/
Professional Licensure & Credentials**
- 💧 **We are Celebrating Our 10th Anniversary!**

Hydraulic Conductivity (K)

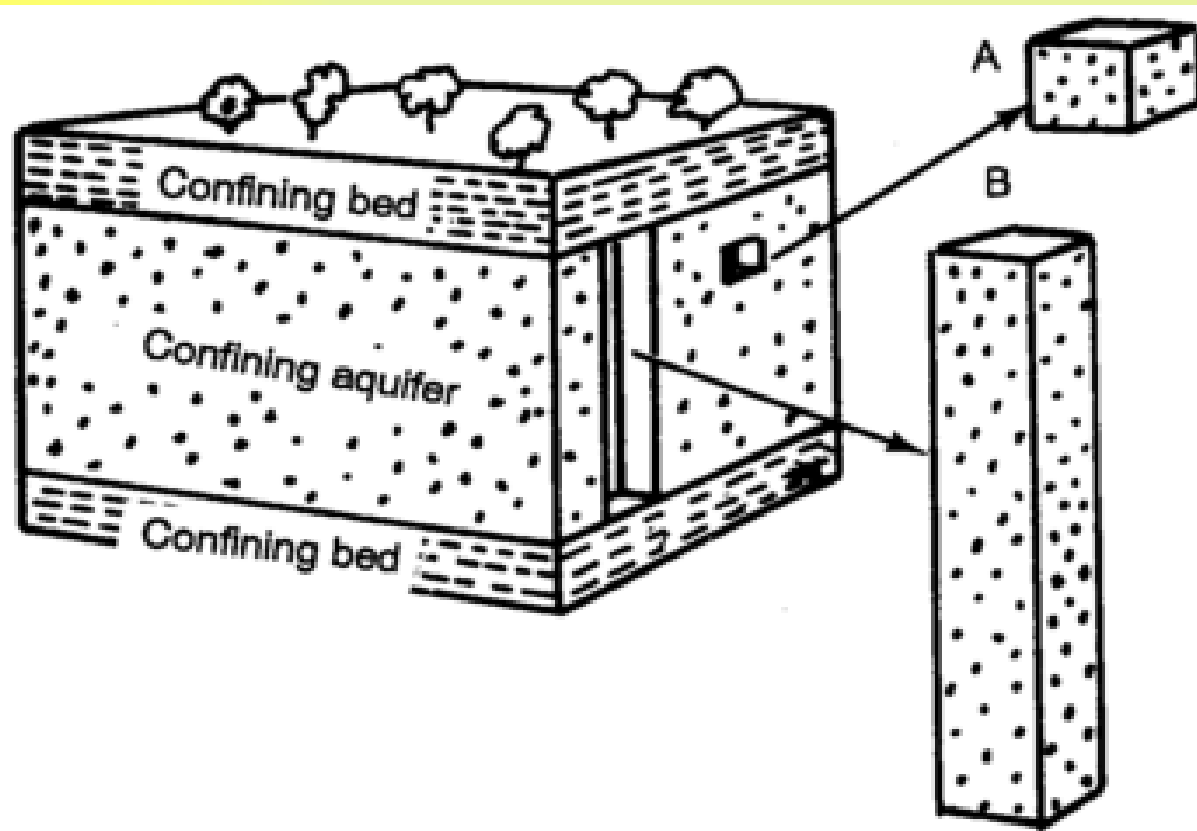


Figure 2-9. Difference between hydraulic conductivity and transmissivity

**Capacity to
Transmit
Water**

**Remember
Darcy?
 $Q=KIA$**

**Length Units
(ft/day)**

Uses of Hydraulic Conductivity (K)

- 💧 **Contaminant Fate and Transport Models**
- 💧 **Hydrologic Balance Evaluations**
- 💧 **Groundwater Mounding Estimates**

Data Sources for K

- 💧 **Slug Tests**
- 💧 **Pumping Tests (Derivable from Transmissivity)**
- 💧 **Literature**

Hypothesis (and Concern)

- 💧 **In theory, K is an Innate Hydrogeologic Property of the Aquifer**
- 💧 **We Scientists Hope/Expect K to be Insensitive to Variances in Measurement Technique (Field and Office)**
- 💧 **K Variability Should Reflect the Aquifer; It Should Not be A Function of What We Do and How**

What is a Slug Test?



💧 **Bail In/Out**

💧 **Rising Head**

💧 **Falling Head**

Slug Test Design Considerations



- 💧 **Borehole Radius**
- 💧 **Geologic Log**
- 💧 **Water Level**
- 💧 **Stratigraphy**
- 💧 **Saprolite/Rock**

Well Construction is Important



💧 $Q = KiA$

💧 Casing Radius

💧 Screen Length
/Interval

💧 Gravel Interval

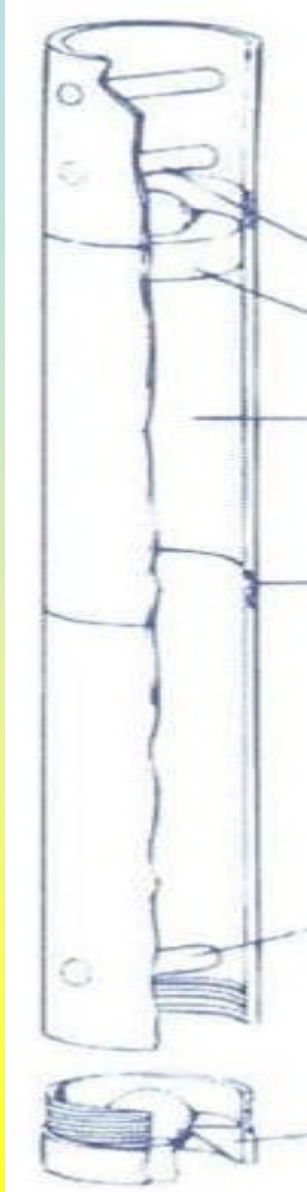
💧 Gravel Porosity

$1 - (\text{bulk density/quartz density}) * 100$

Well Development – This is Key!



Field Methods for Slug Testing

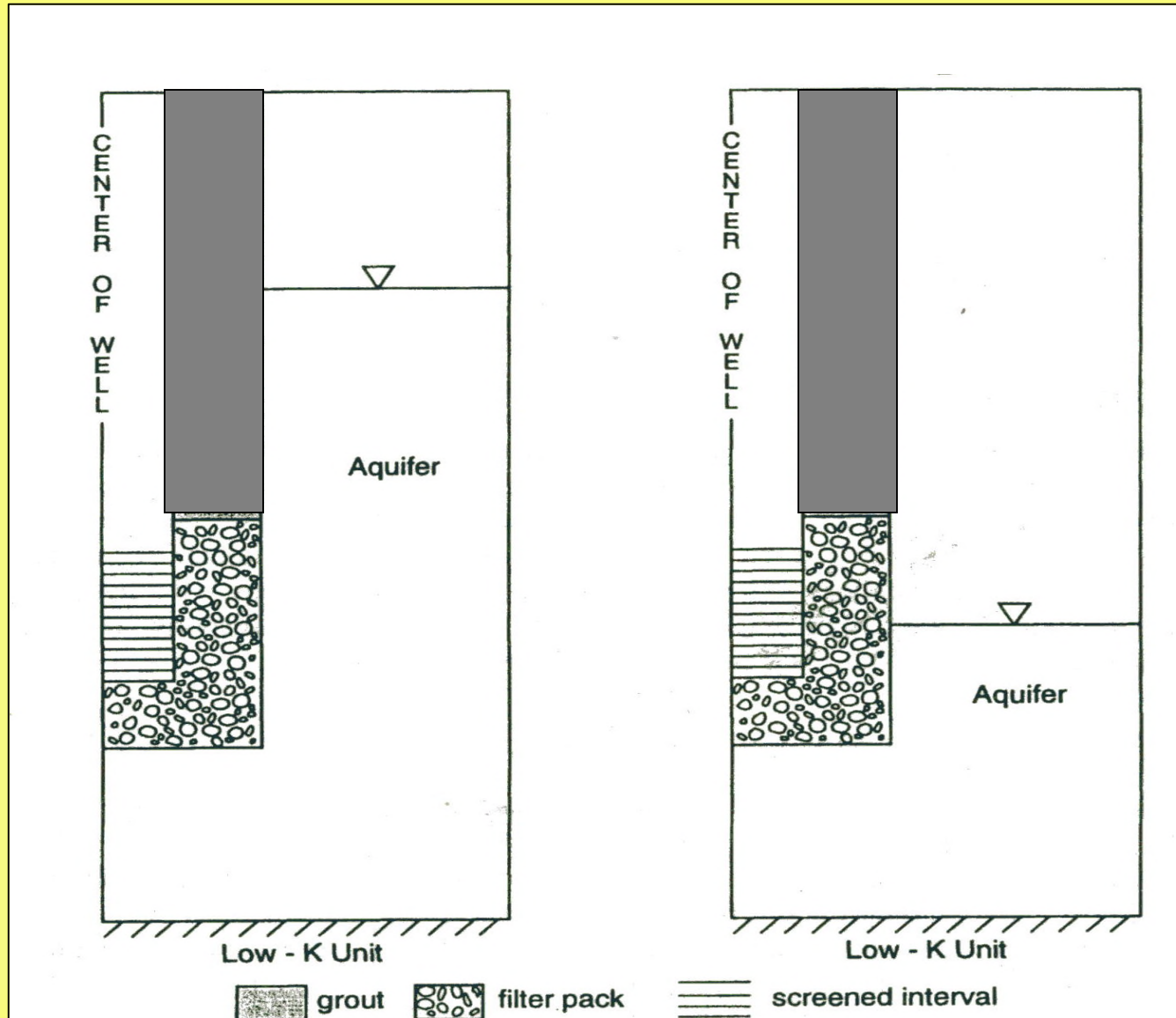


QA/QC Measures Enhance Defensibility



- 💧 **Data Loggers**
- 💧 **One Second Readings**
- 💧 **Equilibrate**
- 💧 **Recovery**
- 💧 **Multiple Tests**

Unconfined Aquifers

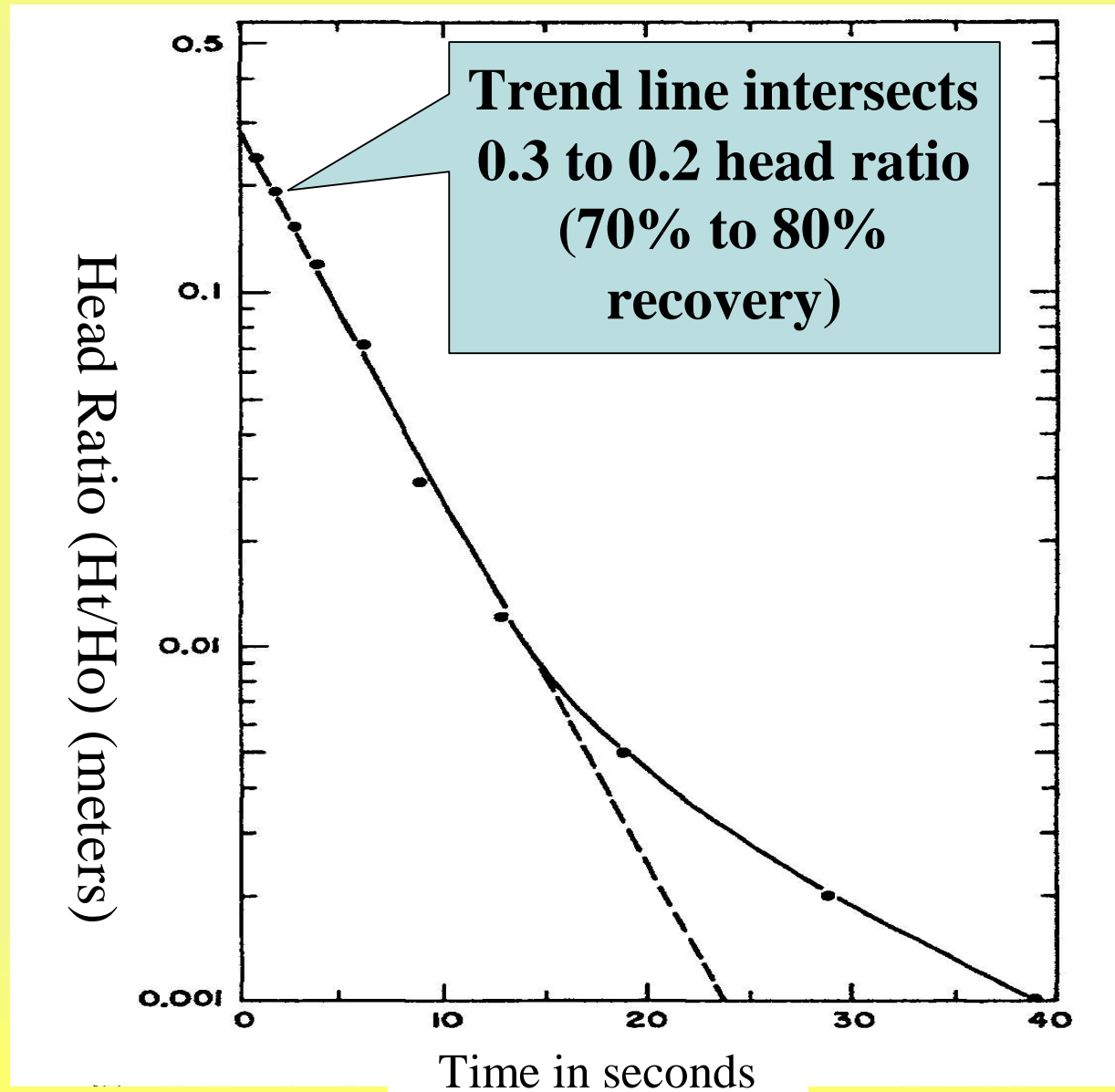


Butler, James J. 1998. The Design, Performance, and Analysis of Slug Tests. CRC Press LLC: Boca Raton, FL.

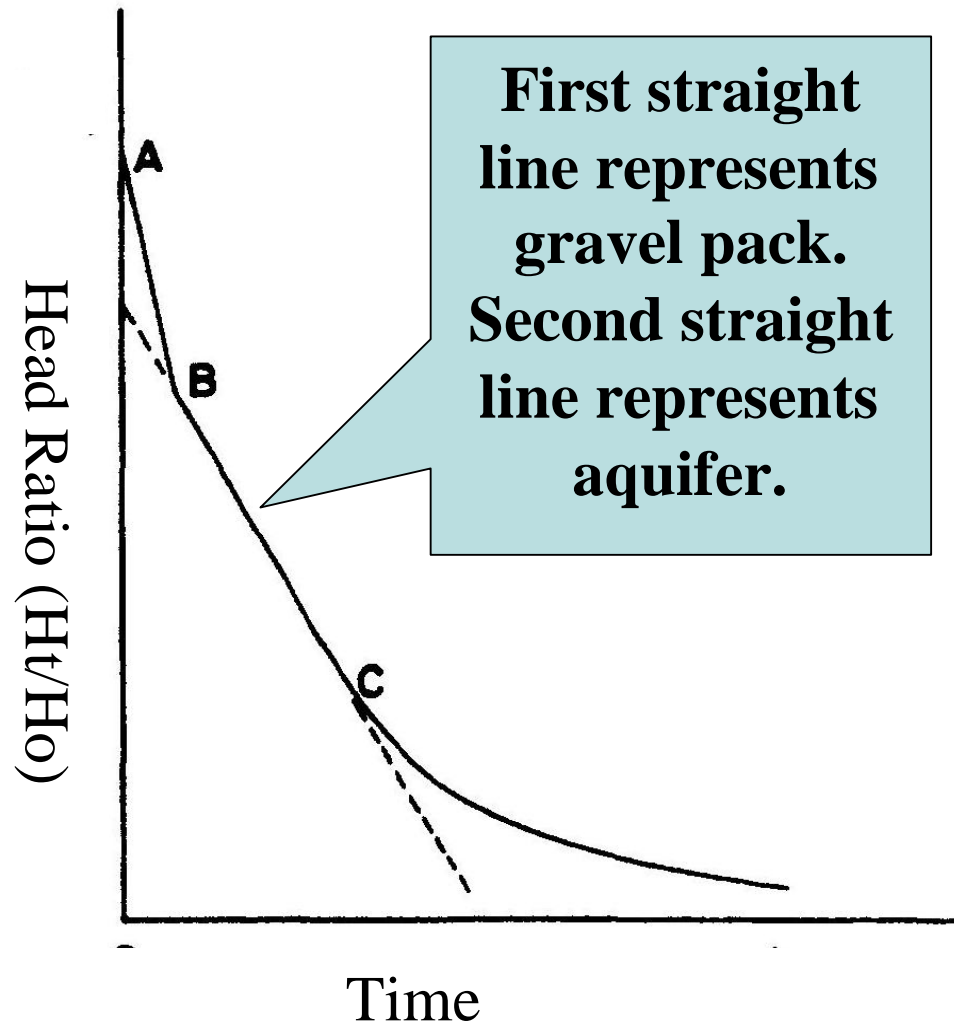
Standard Data Analysis Options

- 💧 **Bouwer and Rice (1976) Method**
- 💧 **Bouwer (1989) Update**
- 💧 **Starpoint Software, Inc. 1994 – 2006**
Super Slug Version 3.2.0.0

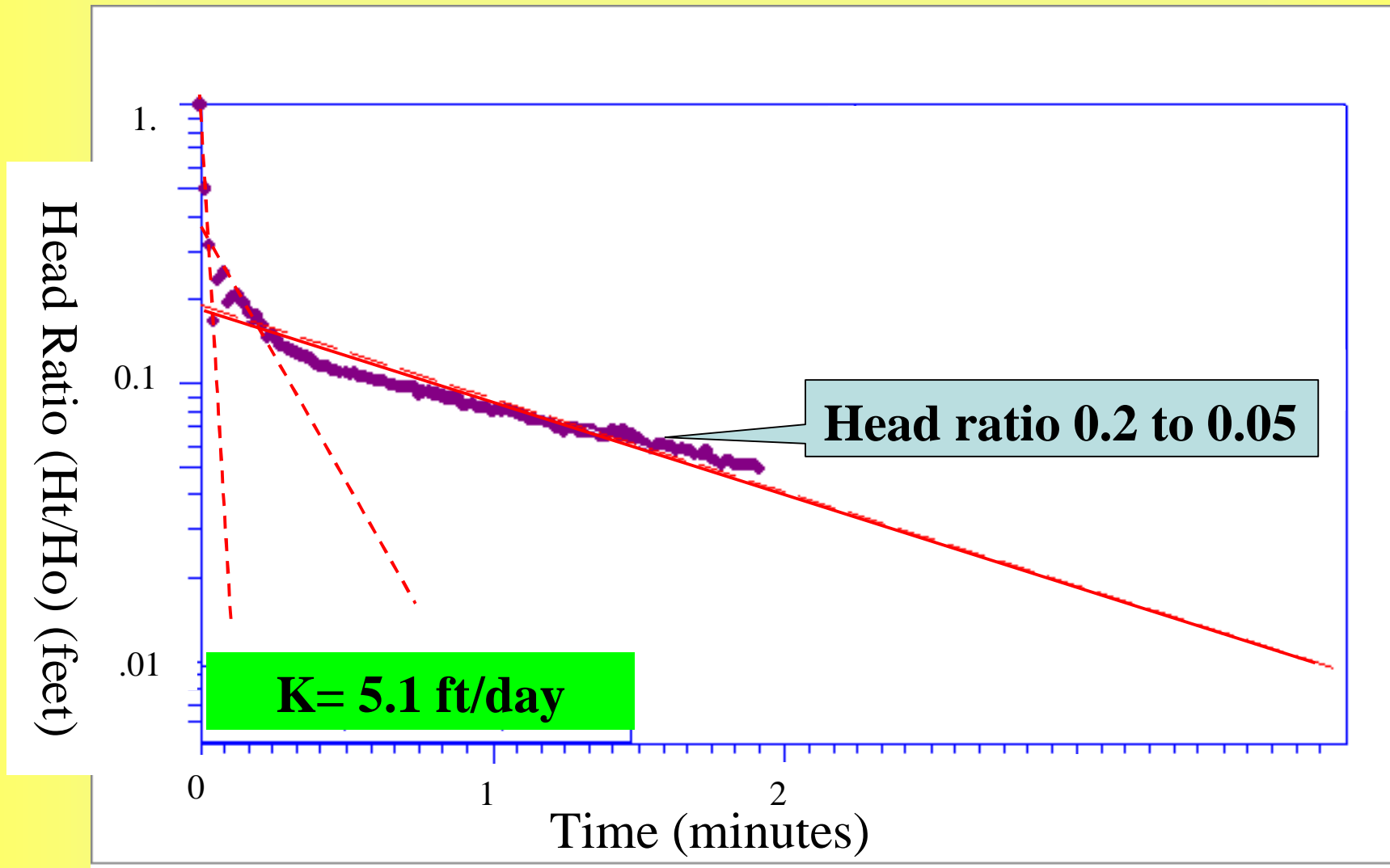
Time vs. Head Ratio (Recovery)



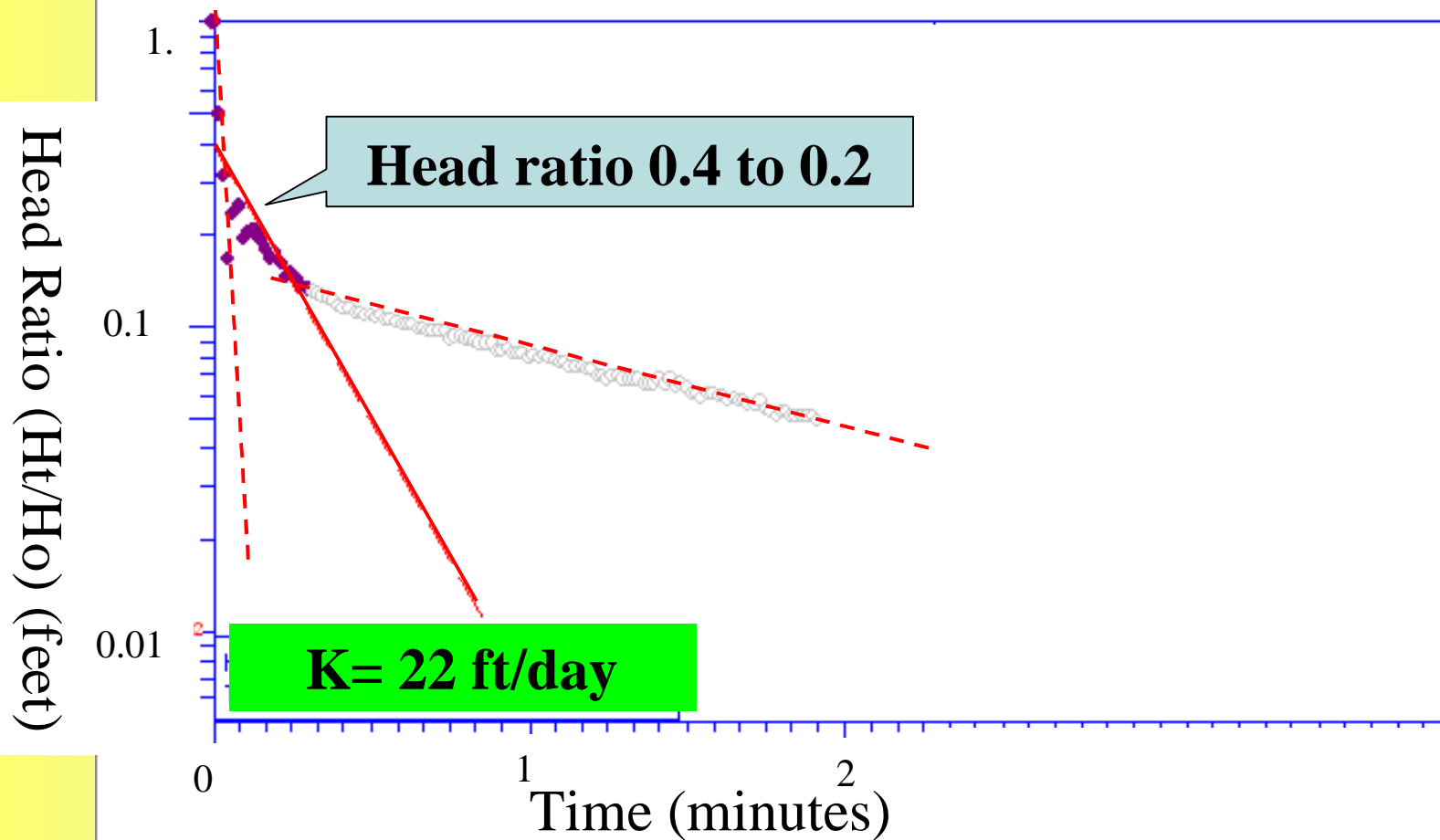
Gravel Pack Correction



Bouwer and Rice Graph



Trend Fit Challenges

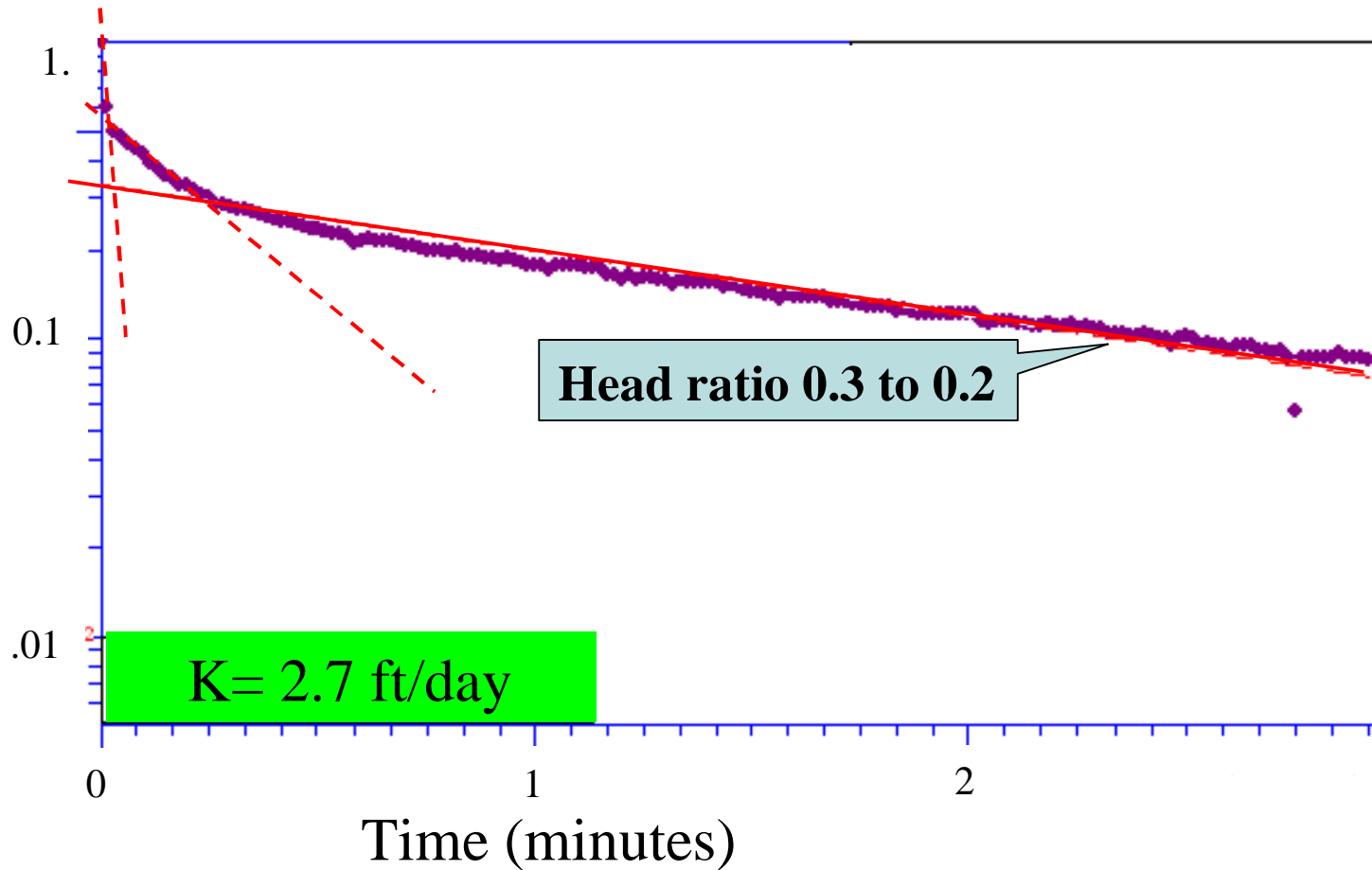


K Dependent on Head Ratio?

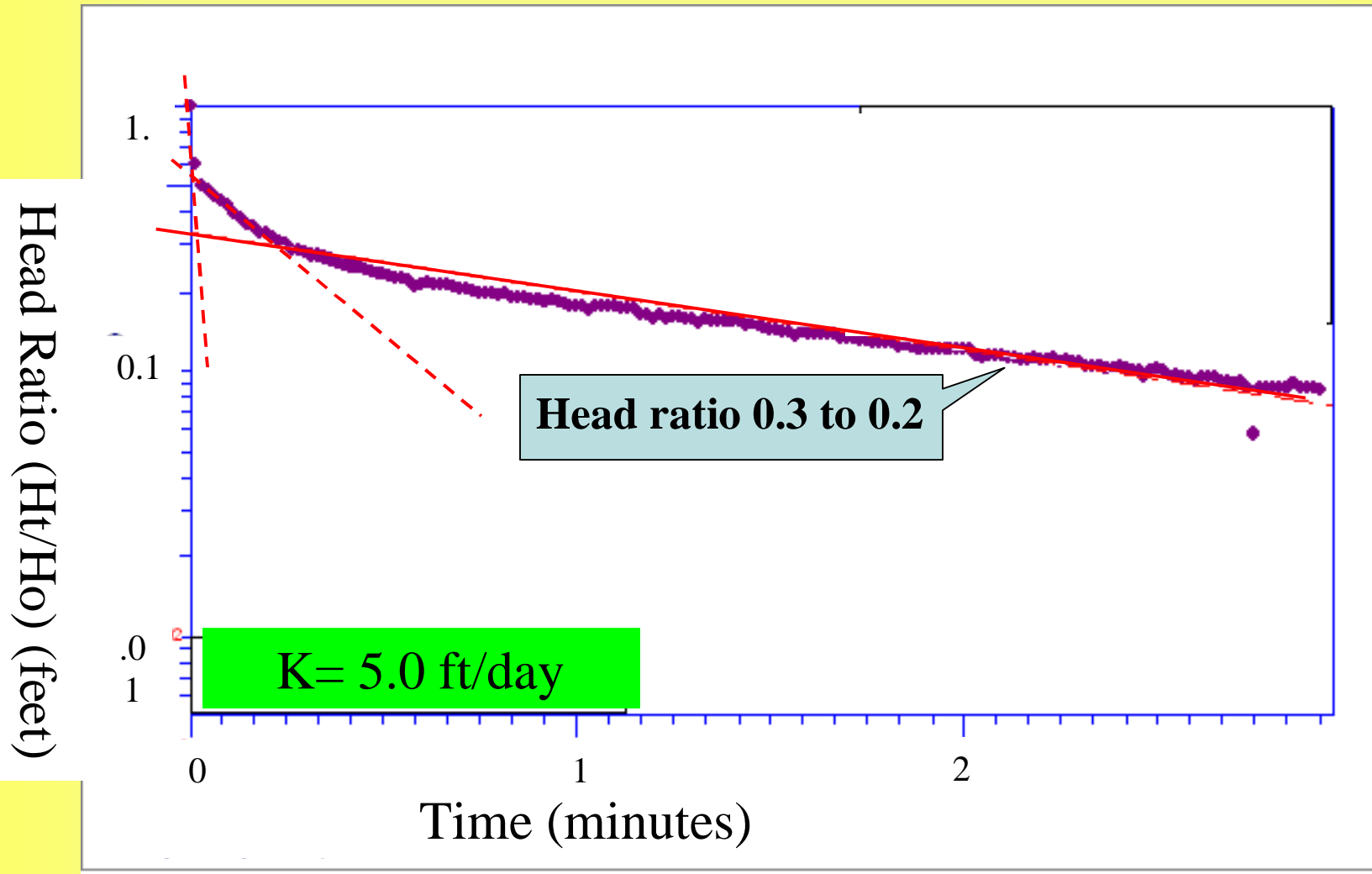
K Values (Coastal Plain)	
Interpreted Head Ratio	Resultant K
Head Ratio 0.2-0.05	5.0
Head Ratio 0.4-0.2	22

No Gravel Pack Correction

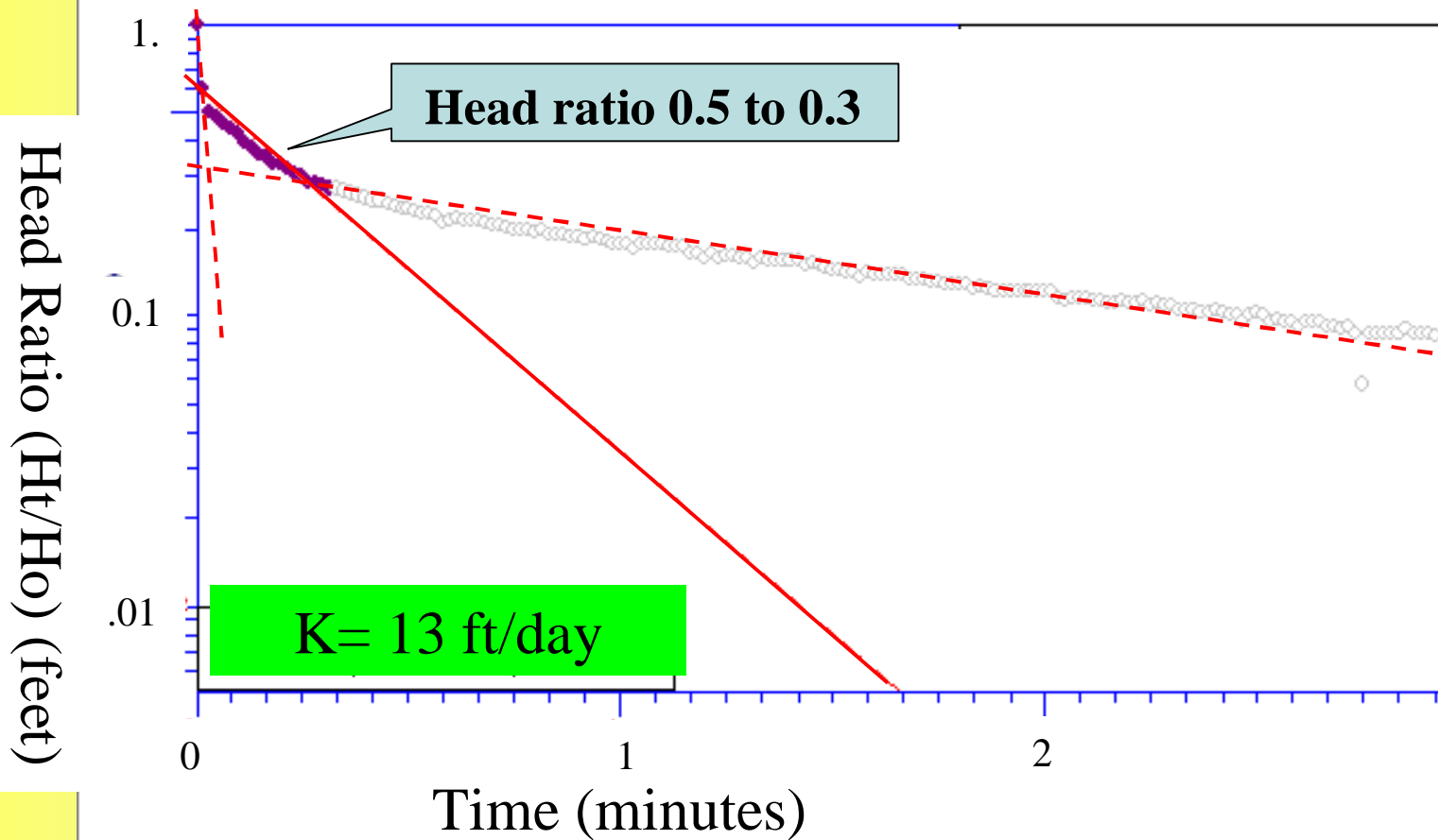
Head Ratio (H_t/H_o) (feet)



Same Data: Gravel Pack Correction

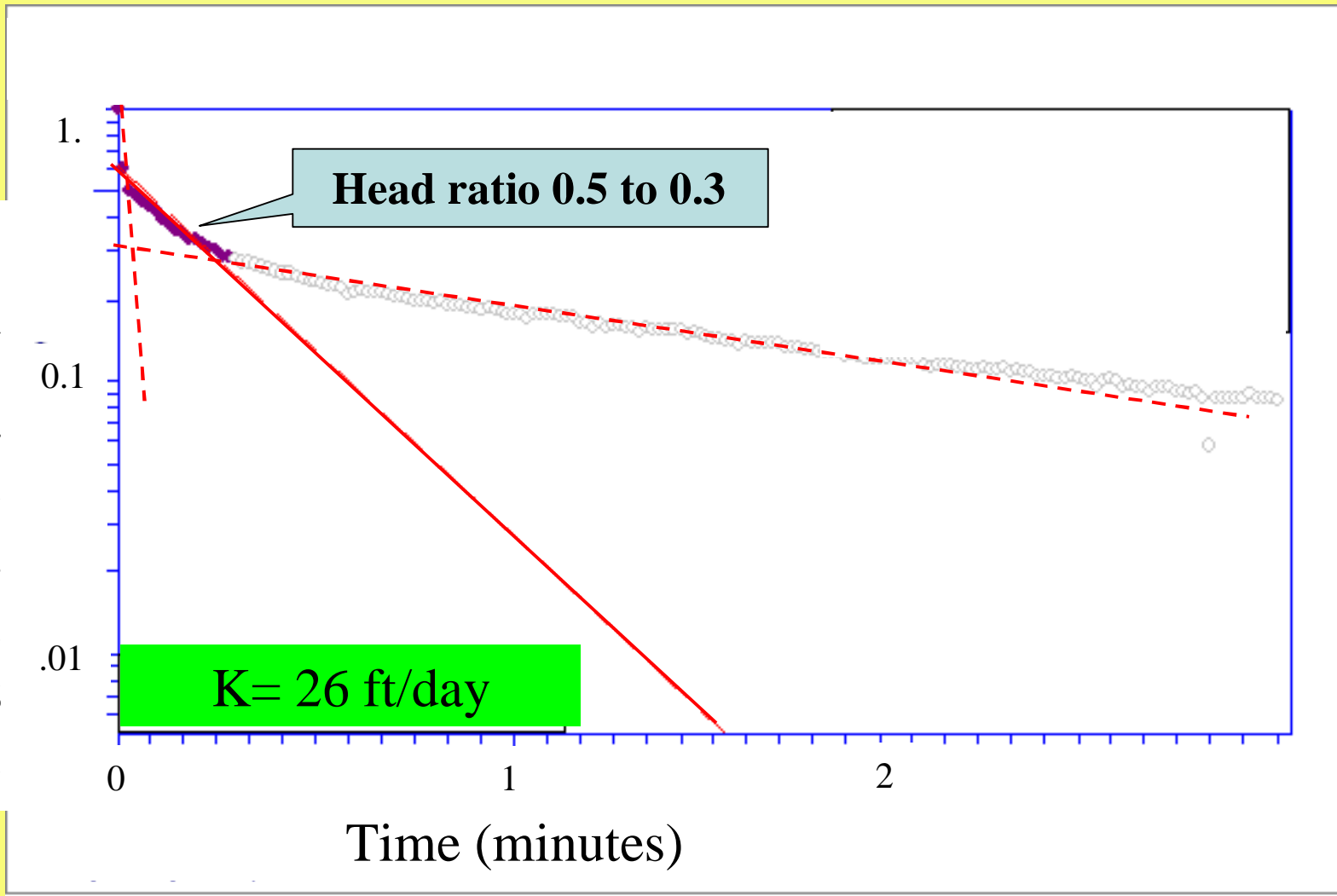


2nd Example: No Gravel Pack Corr.



2nd Example: Gravel Pack Corr.

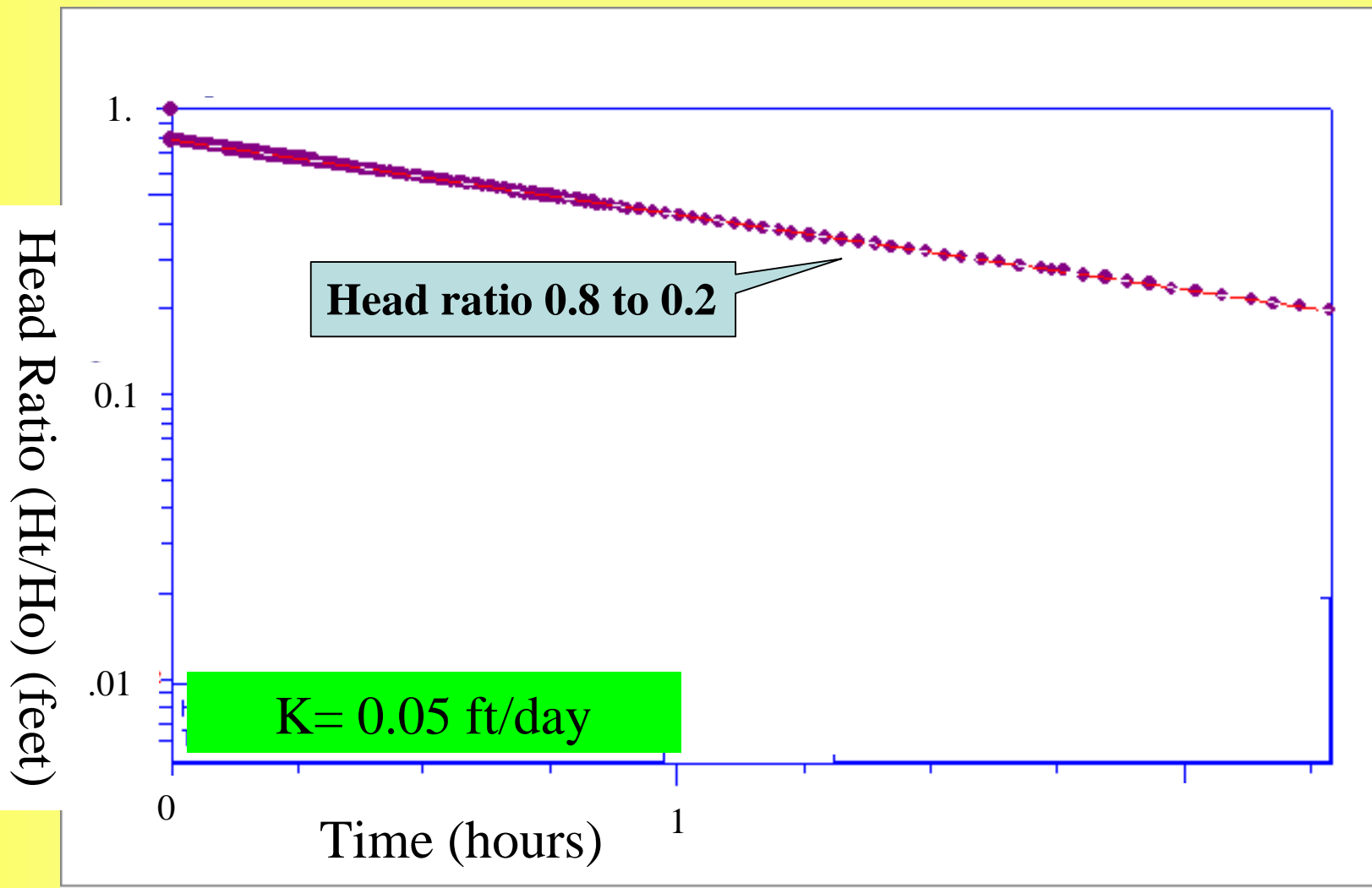
Head Ratio (H_t/H_o) (feet)



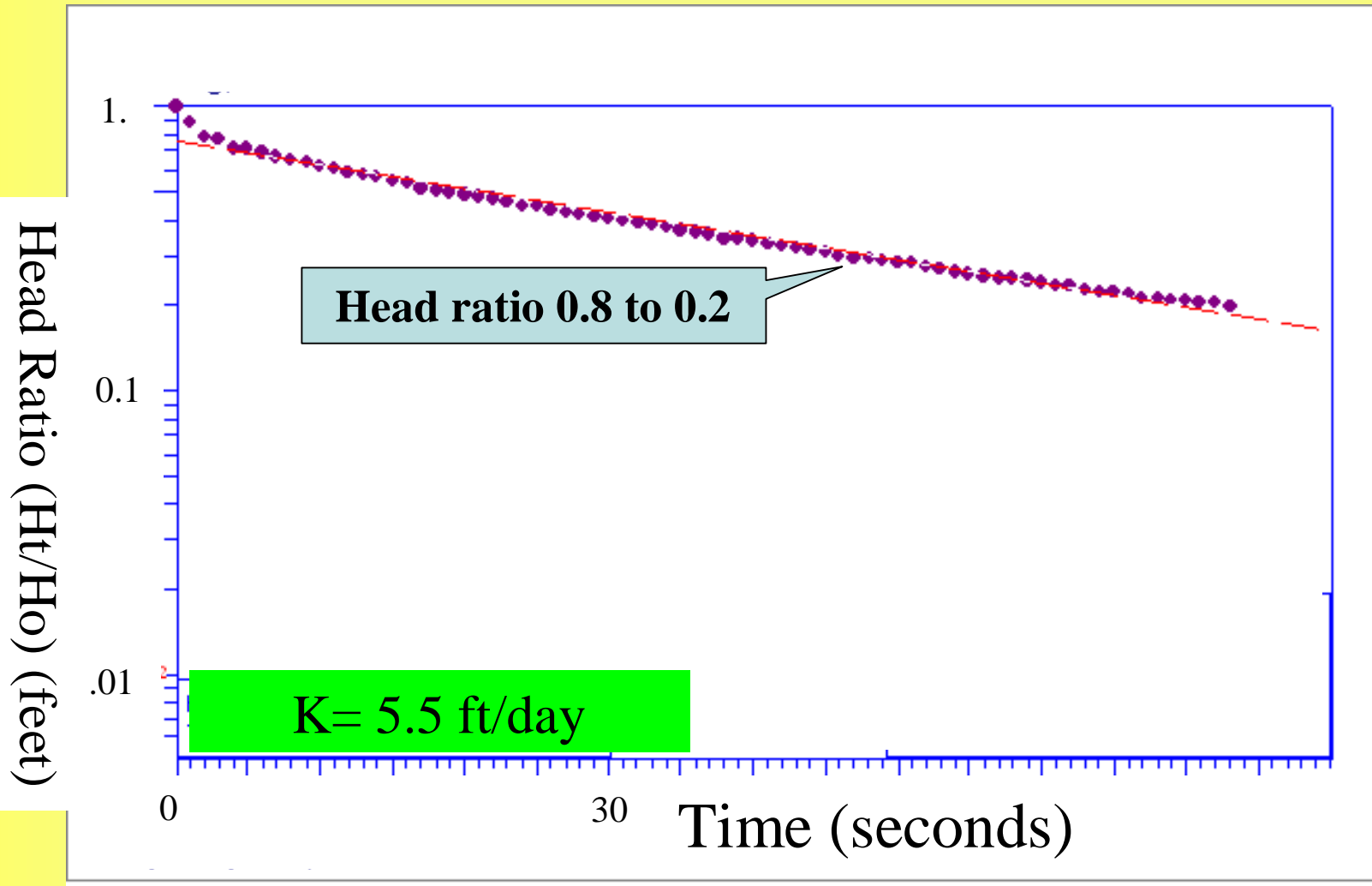
Using GPC Doubles Resultant K

K Values (Union Bridge Well)		
Head Ratio	Gravel Pack Correction Used?	Resultant K
0.3-0.2	No	2.7
0.3-0.2	Yes	5.0
0.5-0.3	No	13
0.5-0.3	Yes	26

No GPC – Low Yield Well



No GPC – High Yield Well



What is the K for the “Site”?

K Values (Low vs. High Yield Piedmont Wells)

Well Setting	Graphical Solution
Off Fracture	0.05
On Fracture	5.5

K is Aquifer Dependent But Also...

- 💧 **K Depends Sharply on Field & Data Eval. Methods**
- 💧 **Not Using GCF Can Lead to K Values “Too Low”**
- 💧 **Assuming Low K (Always) is Better? - May be Myopic!**
- 💧 **Fate and Transport: Low K May Yield False Sense of Security (Contaminant is Not Coming Too Fast)**
- 💧 **Accuracy Should be the Goal, Not Lowest K Possible – This Maximizes Return on Study Investment**

Recommendations Going Forward

- 💧 **Test Repeatedly: Multiple Iterations / Wells**
- 💧 **Choose Methods with Care (Read the Papers)**
- 💧 **Clearly State Assumptions and Limitations**

References

- 💧 **Bouwer, Herman. 1989. The Bouwer and Rice Slug Test – An Update. Groundwater 27 (3).**
- 💧 **Bouwer, H. and Rice, R.C. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research 12 (3).**
- 💧 **Butler, J.J. Jr. 1998. The Design, Performance, and Analysis of Slug Tests. Lewis Publishers: Washington D.C. 252 p.**
- 💧 **Butler, J.J. Jr. 1996. Slug Tests in Site Characterization: Some Practical Considerations. Environmental Geoscience Volume 3(3) 154 p.**



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